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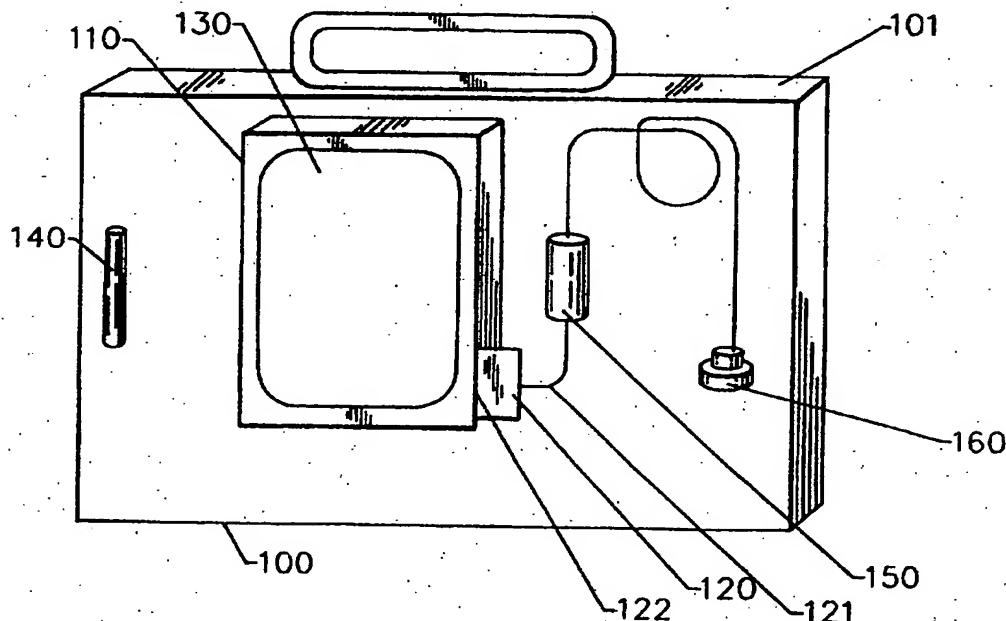
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## (54) Title: PORTABLE, SELF-CONTAINED DATA COLLECTION SYSTEMS AND METHODS

## (57) Abstract

A portable self-contained data collection system (100) for measuring and collecting vibration data from machines includes an accelerometer (160) which is coupled to the analog input of a data acquisition card (120). The data acquisition card (120) samples and digitizes the analog signal to produce a time domain digital signal. The data acquisition card output (122) is coupled to a battery-powered portable computer (110). The battery-powered portable computer (110) includes a database (220) having machine identifications and associated measurement parameters. The portable computer (110) processes the time domain digital signal according to the measurement parameters associated with a selected machine identification, and produces a frequency domain digital signal by performing a Fast Fourier Transform and other digital signal processing operations. The frequency domain signal is also analyzed in the portable computer (110) to produce predictive maintenance information. A power supply (150) for supplying power to the accelerometer (160) is also included. The accelerometer power supply (150) electrically and mechanically couples the accelerometer (160) to the data acquisition card (120). It supplies power to the accelerometer (160) when the data acquisition card is activated. The portable self-contained data collection system (100) can be used to measure and collect vibration data from machines and to analyze this data to produce predictive maintenance information.



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## PORTABLE, SELF-CONTAINED DATA COLLECTION SYSTEMS AND METHODS

### Field of the Invention

This invention relates to predictive maintenance systems and methods, and more particularly to computer-based data collection systems and methods 5 for measuring and collecting vibration data from machines.

### Background of the Invention

Data collection systems and methods are now widely used for measuring and collecting vibration data 10 from machines, for predictive maintenance purposes. Data collection systems typically include two major components: a portable data collector and a host computer. The portable data collector is typically a dedicated instrument to which accelerometers can be 15 coupled, and which stores accelerometer-based vibration data for a machine. An example of a state-of-the-art data collector is the EMONITOR® dataline™ data collector marketed by Entek Scientific Corporation, assignee of the present application. The EMONITOR® 20 dataline™ data collector is described in a manual entitled "EMONITOR® for Windows EMONITOR® dataline™ (U.S.) Data Collector User's Guide, First Edition 1995", Manual No. EEW2501A, published by Entek Scientific Corporation, the disclosure of which is 25 incorporated herein by reference.

The host computer is typically a standard PC-based computer which runs predictive maintenance data management and analysis software thereon. The host software allows a user to set up a database to model

the machinery for which vibration data is to be obtained. The software allows lists of machines to be set up for data collection. Each list includes a set of measurement parameters that control where and how to take and store a measurement. The host software allows one or more lists to be loaded into the data collector for collection. The user then takes the data collector to a machine to be measured, accesses the measurement parameters for that machine, and collects and stores vibration and other information. After collection, the data is unloaded from the data collector to the host. The host software then allows the data to be analyzed. Reports can be generated, including reports of measurements that exceed alarms. Graphical displays of the data can be produced, including trend, spectrum, frequency trend, time waveform and spectrum map plots.

An example of data management and analysis host software is EMONITOR® for Windows, which is marketed by Entek Scientific Corporation, the assignee of the present invention. The EMONITOR® for Windows software is described in a manual entitled "EMONITOR® for Windows User's Guide, Second Edition 1994", Manual No. EEW0002B, published by Entek Scientific Corporation, the disclosure of which is incorporated herein by reference.

In state-of-the-art manufacturing environments, the capital investment in machinery can be staggering. Accordingly, there is a great need for predictive maintenance to prevent machine breakdowns and increase reliability. Moreover, with "just in time" manufacturing requirements, predictive maintenance becomes even more critical to eliminate machine down time. Accordingly, there is a great need for data collection systems and methods.

Unfortunately, the high cost of data collection systems is often a barrier to their widespread use. The high cost is in part related to

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the use of special purpose hardware and software in the data collector. In addition to high cost, the use of special purpose hardware and software limits the flexibility of the data collector and makes it difficult to update and improve the data collector. Although portable computers, laptop computers, pen-based computers, palmtop computers and Personal Digital Assistants (PDA) have become widely available, they have not yet made a significant impact on data collectors. See for example, the publication in Automatic ID News, April 1995, entitled "Be Ready for Technology Leap at the End of the Century: Three Non-ADC Developments to Springboard Automatic Data Capture Growth". See also the publication in Maintenance, January/February 1995, by Billson et al. entitled "Portable Pen Computers - An Essential Tool for the Mobile Maintenance Engineer".

#### Summary of the Invention

The present invention is a portable, self-contained data collection system for measuring and collecting vibration data from machines. The system includes an accelerometer including a motion sensitive transducer and an accelerometer output. The accelerometer is coupled to a machine to produce an analog signal at the accelerometer output. The system also includes a data acquisition card having an analog input and a digital output. The accelerometer output is electrically coupled to the analog input. As used herein, electrical coupling includes wireless, optical or conventional wire coupling. The data acquisition card samples and digitizes the analog signal to produce a time domain digital signal, i.e. a sampled and digitized series of voltage versus time points, at the digital output. The system also includes a battery-powered portable computer such as a pen-based computer, which includes an expansion slot. The data acquisition

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card digital output is electrically and mechanically connected to the expansion slot.

The battery-powered portable computer also includes a database having machine identifications and 5 associated measurement parameters. User input means such as a pen allows user selection of a machine identification for measurement. The portable computer also includes signal processing means for processing the time domain digital signal according to the 10 measurement parameters associated with the selected machine identification. Preferably, the signal processing means processes the time domain digital signal to produce a frequency domain digital signal by performing a Fast Fourier Transform (FFT), wavelet or 15 other digital signal processing operations. Finally, the battery-powered portable computer also preferably includes signal analyzing means for analyzing the frequency domain digital signal to produce predictive maintenance information such as spectral distribution. 20 The time domain digital signal can also be analyzed to produce crest factor and other predictive maintenance information.

A data collection system according to the present invention uses a standard portable computer 25 such as a pen-based computer and a standard data acquisition card such as a PCMCIA sound card, to provide portable self-contained hardware for data collection and analysis. The machine database, signal processing means and signal analyzing means are 30 preferably implemented using software modules which execute on the portable computer. The machine database and the signal analyzing software may be provided using EMONITOR® for Windows or other predictive maintenance software on the portable computer. Signal processing 35 software may be provided by conventional digital signal processing software which provides digital filtering, integration from acceleration to velocity or

displacement units, Fast Fourier Transform or other mathematical functions, and averaging. Accordingly, a low cost self-contained data collection system is provided.

5 It will be understood that since the portable data collection system includes a database, signal processing software and signal analyzing software therein, a host computer connection is not required for operation. Rather, all predictive maintenance  
10 operations may be performed using only the portable self-contained data collection system. However, it will also be understood by those having skill in the art that the portable self-contained data collection system can be used as part of a networked data  
15 collection system wherein the portable computer includes transmitting means for transmitting at least one of the machine identifications, the measurement parameters, the time domain digital signal, the frequency domain digital signal or the predictive  
20 maintenance information to a second computer. The second computer may store this data for distribution to other users and the second computer or other users may also perform one or more of the processing functions of the portable data collector. The transmitting means is  
25 preferably wireless, such as a radio frequency (RF) transmitter. However, transmission may also be accomplished by uploading information to another computer using conventional wire communications.

According to another aspect of the present  
30 invention, the portable self-contained data collection system also includes a power supply for supplying power to the accelerometer. In particular, conventional portable computers do not provide sufficient power for an accelerometer, which typically requires 24V at 2mA.  
35 According to the invention, an accelerometer power supply electrically and mechanically couples the accelerometer output to the data acquisition card

analog input. The accelerometer power supply is preferably responsive to the data acquisition card for supplying power to the accelerometer when the data acquisition card is activated, and for deactivating 5 when the data acquisition card is deactivated.

In particular, the accelerometer power supply includes a power supply housing and an accelerometer battery power supply in the power supply housing which provides sufficient power for an accelerometer. Output 10 means including an output connector electrically and mechanically connects the accelerometer battery power supply to an accelerometer and receives accelerometer signals from the accelerometer. Input means including an input connector electrically and mechanically 15 connects the accelerometer battery power supply to an external device, preferably the analog input of a data acquisition card. The input means receives a control signal from the external device, and also passes the accelerometer signals to the external device. The 20 accelerometer battery power supply is responsive to the control signal, to activate the accelerometer battery power supply to supply battery power for an accelerometer to the output connector. In the absence of the control signal, the accelerometer battery power 25 supply is deactivated. Preferably, the accelerometer battery power supply will pass signals from the output means to the external device in the absence of the control signal, so that non-powered transducers can be used.

When the accelerometer power supply is included, the portable self-contained data collection system includes three hardware components: a portable computer, a data acquisition card and an accelerometer power supply. The portable computer includes a 30 portable computer housing, a portable computer battery power supply within the portable computer housing to supply power to the portable computer, and an expansion 35

slot in the portable computer housing. The data acquisition card is mechanically and electrically coupled to the expansion slot. The accelerometer power supply includes a power supply housing, and an 5 accelerometer battery power supply within the power supply housing which provides sufficient power for an accelerometer. The accelerometer power supply is electrically and mechanically coupled to the data acquisition card and the accelerometer is electrically 10 and mechanically coupled to the accelerometer power supply. The portable computer, data acquisition card and accelerometer power supply may be packaged in a ruggedized carrying case. The portable computer executes software including a database including 15 machine identifications and measurement parameters, signal processing software for processing accelerometer signals and signal analyzing software for analyzing the processed signal to produce predictive maintenance information.

20 Data collection methods according to the present invention are used for measuring and collecting vibration data from machines, wherein the following steps are all performed in a portable battery-powered computer: A machine identification for measurement is 25 selected. A time domain accelerometer signal is processed according to measurement parameters associated with the selected machine identification to produce a digital signal. The digital signal is analyzed to produce predictive maintenance information. 30 If necessary, the processing step is preceded by the step of sampling and digitizing an analog accelerometer signal to produce the time domain accelerometer signal. The machine identifications, measurements, time domain signal, digital signal and/or predictive maintenance 35 information can be displayed on the portable battery-powered computer. Portable self-contained data collection systems and methods are thereby provided.

In addition, this information can be transferred to another computer.

#### Brief Description of the Drawings

Figure 1 illustrates a data collection system 5 for collecting vibration data from machines according to the present invention.

Figure 2 is a block diagram illustrating a data acquisition card interfaced to an operating system, database, signal processing means and signal 10 analyzing means implemented in a battery operated portable computer according to the present invention.

Figure 3 is a block diagram illustrating signal processing means, including filtering, integration, fast Fourier transform, and averaging, for 15 processing a time domain digital signal according to the present invention.

Figure 4 is a block diagram illustrating a power supply for an accelerometer according to the present invention.

20 Figures 5a-5b illustrate data collection operations according to the present invention.

Figures 6a-6c are computer screen images illustrating a machine identification selection according to the present invention.

25 Figure 7 is a computer screen image illustrating signal analyzing according to the present invention.

Figure 8 is a diagram illustrating a data collection system implemented in a battery operated 30 portable computer linked to other computers in a computer network according to the present invention.

#### Detailed Description of Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the 35 accompanying drawings, in which preferred embodiments

of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so 5 that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Referring now to Figure 1, data collection 10 system 100 is illustrated, housed in a case 101. As shown, data collection system 100 includes a battery-powered portable computer 110 mating to data acquisition card 120, display means 130, user input means 140, power supply 150, and accelerometer 160.

15 The construction of battery powered portable computer 110 is well-known to those skilled in the art. Battery operated portable computers typically include a microprocessor, associated random access memory (RAM), nonvolatile data storage such as a hard disk drive, a 20 battery power source and expansion slots designed to accommodate circuit boards electrically coupling the computer components to external devices such as keyboards, pens, mouses, transducers and displays. These expansion slots typically accommodate standard 25 form factor circuit cards, such as the industry-standard PCMCIA form factor cards used in notebook and laptop computers. For field uses, such as monitoring of machinery for predictive maintenance purposes, battery operated portable computer 110 may be mounted 30 in a lightweight, rugged hand-held case 101, and user input means 140 may include a magnetic pen designed to operate with a magnetically sensitive screen matrix. An example of a typical battery operated portable computer designed especially for field use is the 35 Fujitsu Stylistic 500, as described in Fujitsu brochure 58-0349-00B, the disclosure of which is incorporated herein by reference. This computer is referred to for

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purposes of explanation only, and it will be understood by those skilled in the art that the present invention may be used with other portable computers.

Data acquisition card 120 is an analog to digital (A/D) converter card that mechanically and electrically couples data acquisition card 120 to an expansion slot in battery powered portable computer 110, electrically connecting digital output 122 to battery operated portable computer 110. Data acquisition card 120 is electrically coupled to accelerometer 160 at analog input 121. Typically, data acquisition card 120 is a low-cost standard form factor sound card designed to receive audio frequency analog signals at analog input 121. An example of such a sound card is the Magic Ram PCMCIA 16-bit audio adapter, which is described in a manufacturer's data sheet entitled "PCMCIA 16-bit Audio Adapter," the disclosure of which is incorporated herein by reference. This device is a standard PCMCIA form factor card that mates with a PCMCIA expansion slot. It will be understood by those skilled in the art that a data acquisition card according to the present invention includes any A/D converter card capable of receiving analog inputs and transmitting corresponding digital signals to a battery operated portable computer through a digital communications port, such as an expansion slot. It will also be understood by those skilled in the art that the present invention may be used with a battery operated portable computer 110 which includes an analog input and associated internal A/D.

Accelerometer 160 produces an analog signal corresponding to the accelerations experienced by a motion sensitive transducer included therein, and is electrically coupled to data acquisition card 120 by analog input 121. The motion-sensitive transducer is typically piezoelectric and produces a voltage

proportional to the acceleration of the transducer. The accelerometer includes means for coupling the motion sensitive transducer to a machine from which the user desires vibration data, such as a probe extension, 5 screw or magnet attached to the accelerometer structure. Examples of piezoelectric accelerometers may be found in Catalog QSG-200, published by Industrial Monitoring Instrumentation Division of PCB Piezotronics, Inc., the disclosure of which is 10 incorporated herein by reference. It will be understood by those skilled in the art that the present invention may be used with other measurement devices producing analog output signals corresponding to accelerations, such as piezotransistor or variable 15 resistance accelerometers.

Power supply 150 supplies electrical power to accelerometer 160, receives output signals from accelerometer 160, receives control signals from data acquisition card 120, and conveys output signals from 20 accelerometer 160 to data acquisition card 120. Power supply 150 is mechanically and electrically coupled to both accelerometer 160 and data acquisition card 120.

Referring now to Figure 2, a block diagram illustrates accelerometer 160, data acquisition card 25 120 and user input means 140 interfaced to an operating system 200, data collection interface 210, database 220, signal processing means 230 and signal analyzing means 240. Operating system 210 is typically executive software that controls data collection interface 210, 30 database 220, signal processing means 230, signal analyzing means 240, and data acquisition card 120, responsive to commands received through user input means 140. Such commands may be to acquire or store data, or to perform filtering, time domain analysis, or 35 frequency domain analysis. An example of operating system 200 is Entek Scientific Corporation's EMONITOR® for Windows data management software, as described in

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"EMONITOR® for Windows User's Guide, Second Edition 1994," Manual No. EEW0002B, the disclosure of which is incorporated herein by reference. This software is a Windows-based program that enables a user to perform 5 database manipulation, data analysis or other operations via manipulation of screen icons. It will be understood by those skilled in the art that the present invention may be used, for example, with other operating systems running in a Windows, DOS, or UNIX 10 environment.

Database 220 comprises a plurality of machine identifications and associated measurement parameters. Database 220 may have a hierarchical, relational or other structure and is typically organized according to 15 logical relationships between particular machines. An example of a hierarchical database structure is incorporated in Entek Scientific Corporation's EMONITOR® for Windows, as described in Chapters 4 and 5 of "EMONITOR® for Windows User's Guide, Second Edition 20 1994," Manual No. EEW0002B. This database is a SQL database that organizes machine identifications, and associates parameters such as machine location, signal processing parameters and previously measured data values with these machine identifications. This 25 database is referred to for purposes of explanation, and it will be understood by those skilled in the art that the present invention may be used with other hierarchical or non-hierarchical database structures, and may include various combinations of machine 30 parameters.

Data collection interface 210 is preferably a software module that controls the operation of data acquisition card 120 and signal processing means 230 through operating system 200, although hardware or 35 software/hardware combinations may be employed. Upon commands from data collection interface 210, data acquisition card 120 samples and digitizes an analog

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signal 115 received from a accelerometer 160 and provides a corresponding time domain digital signal 125, which is conveyed to signal processing means 230. In the embodiment of the present invention shown in 5 Figure 2, data collection interface 210 is a software module operating in conjunction with, for example, an operating system such as EMONITOR® for Windows running in a Windows environment, and is conveniently accessed and controlled by user selection of appropriate icons 10 in a display window.

Although the combination of elements described in Figure 2 envisions data collection, database management and data analysis integrated in a multitasking environment such as Windows, it will be 15 understood by those skilled in the art that the present invention may be practiced using other means of interfacing data acquisition card 120, signal processing means 230, signal analyzing means 240 and database 220. For example, data collection interface 210 may be a standalone software program capable of transferring data from data acquisition card 120 to database 220 for subsequent data management, signal processing and signal analysis. In another arrangement, data acquisition card 120 may include all 20 or a portion of signal processing means 230, allowing sampling, digitizing and processing of analog signal 115 to be performed on data acquisition card 120. An example of such an integrated PCMCIA card is the Bullet <sub>dsp</sub>  card marketed by Communication Automation and 25 Control, Inc. The Bullet <sub>dsp</sub>  card is described in a data sheet entitled "PCMCIA TI TMS320C32," published by Communication Automation and Control, Inc., the disclosure of which is incorporated herein by reference.

30 35 Signal processing means 230 performs digital signal processing of time domain digital signal 125 received from data acquisition card 120. Typically,

signal processing means 230 is implemented in conventional modular software blocks, which may be selected and combined to perform various processing functions, as further illustrated in Figure 3. This 5 software may implement functions such as filtering, fast Fourier transform, integration or averaging, which may be selected and arranged as desired.

Signal analyzing means 240 typically is software that examines processed digital signals 10 received from signal processing means 230 and produces predictive maintenance information. Upon commands received through operating system 200, signal analyzing means 240 conducts analyses such as trend analysis, alarm detection, spectral analysis, data plotting or 15 report generation. An example of signal analyzing means 240 is the analysis software incorporated in Entek Scientific Corporation's EMONITOR® for Windows, as described in Chapters 7, 9, 10 and 11 of "EMONITOR® for Windows User's Guide, Second Edition 1994," Manual 20 No. EEW0002B.

Referring now to Figure 3, a software block diagram illustrates signal processing software for implementing signal processing means 230 which includes modular processing elements 310a-310d which may be 25 selected and combined as required. It will be understood by those skilled in the art that other arrangements of signal processing elements may be used with the present invention. In addition, it will be understood by those skilled in the art that other non- 30 modular signal processing software techniques may be used with the present invention.

Referring now to Figure 4, an electrical block diagram illustrates power supply 150 for accelerometer 160. Power supply housing 410 encloses 35 accelerometer battery power supply 420. Accelerometer battery power supply 420 provides sufficient power to excite an external accelerometer. Output means 430

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electrically and mechanically couples accelerometer battery power supply 420 to an external accelerometer. Typically, output means 430 will include an MS-3106 connector commonly used in accelerometer applications, 5 but it will be understood by those skilled in the art that other structures may be used with the present invention, including coaxial and other types of standard connectors.

Input means 440 electrically and mechanically 10 couples accelerometer battery power supply 420 to an external device, such as an A/D converter, and receives control signal 450 from the external device.

Accelerometer battery power supply 420 may be responsive to control signal 450, deactivating power 15 output to the external accelerometer in the absence of control signal 450, thus offering the capability to minimize power consumption during non-measurement periods and extending battery life or time between recharges.

20 Figure 4 shows accelerometer battery power supply 420 further including battery 422, charging means 424, and regulating means 426. Charging means 424 provides the capability to charge battery 422. Regulating means 426 takes the power output from 25 battery 422 and provides the voltage and current conditioning required to excite the external accelerometer. It will be understood by those skilled in the art that not all of these elements are required for all embodiments of the present invention.

30 Different power supply configurations may, for example, utilize disposable or removable batteries and eliminate the need for internal charging means 424.

Figure 5a illustrates operations for measuring and collecting vibration data from machines, 35 implemented in a battery-operated powered computer. First, in Block 510 a user selects a machine identification for measurement. In Block 520 a time

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domain accelerometer signal 515 is processed to produce a digital signal 525. In Block 530 the digital signal is analyzed to produce predictive maintenance information, such as detection of alarm conditions due to vibration magnitudes exceeding predetermined limits or reports concerning machine vibration parameters. Referring to Figure 5b, in an alternate embodiment, the operations of Block 520 may be preceded by a step of sampling and digitizing an analog time domain accelerometer signal to produce a time domain digital accelerometer signal 516, as shown in Block 511. In addition, predictive maintenance information 526 may then be displayed, as shown in Block 540.

Figures 6a-6b illustrate the selection step of Block 510 of Figure 5a-5b in greater detail. In Figure 6a the user enters a data collection window 600 in which he may select a machine identification for measurement, as shown at 601. The display informs the user of the identification selected, which typically is a location on a particular machine, as shown at 602. The user typically commands data acquisition by selection of an icon, as shown at 603.

The parameters associated with a particular machine identification typically have been previously entered into a database. This may be done manually, as shown in Figure 6b. Within a data entry window 610, the user selects a desired machine identification, as illustrated at 611, and enters the associated parameters, as shown at 612. Alternatively, parameters may be entered with the aid of predetermined machine templates, as shown in Figure 6c. These parameters may include signal processing parameters for use in the processing step of Block 520 of Figure 5, but it will be understood by those skilled in art that other arrangements may be used with the present invention, such as allowing the user to select particular signal

processing parameters while in data collection window 600.

Figure 7 illustrates the signal analyzing operation of Block 530 of Figure 5, specifically the 5 displayed results of a spectrum analysis. It will be understood by those skilled in the art that other analyses may be performed on digital signals, such as magnitude or crest factor calculations or detection of alarm conditions.

10 Figure 8 illustrates the data collection system of the present invention further including transmission of machine identifications, measurement parameters, time domain accelerometer signals, frequency domain digital signals and predictive 15 maintenance information to other computers 820a-820n linked to the battery operated portable computer 110 by means of a network 810. It will be understood by those skilled in the art that network 810 may be hardwired or may employ radio frequency (RF) or other communications 20 links. Under this aspect of the invention, machine-related data may be uploaded from the battery powered portable computer 110 to computers 820a-820n for subsequent data management, processing, analysis or display.

25 In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the 30 invention being set forth in the following claims.

## THAT WHICH IS CLAIMED:

1. A data collection system for measuring and collecting vibration data from machines, said data collection system comprising:
  5. an accelerometer including a motion sensitive transducer, an accelerometer output and means for coupling said motion sensitive transducer to a machine to produce an analog signal at said accelerometer output;
  10. a data acquisition card having an analog input and a digital output, said accelerometer output being electrically coupled to said analog input, said data acquisition card sampling and digitizing said analog signal to produce a time domain digital signal at said digital output;
  15. a battery powered portable computer including an expansion slot, said data acquisition card digital output being electrically and mechanically connected to said expansion slot, said battery powered portable computer further comprising:
    20. a database including a plurality of machine identifications and associated measurement parameters; user input means for user selection of a machine identification for measurement; and signal processing means, for processing said
    25. time domain digital signal according to the measurement parameters associated with the selected machine identification.
2. A data collection system according to Claim 1 wherein said signal processing means comprises
  30. means for processing said time domain digital signal to produce a frequency domain digital signal; said battery powered portable computer further comprising signal analyzing means for analyzing said frequency domain signal to produce predictive
  35. maintenance information.

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3. A data collection system according to  
Claim 1 further comprising means for transmitting at  
least one of said machine identifications, said  
measurement parameters, said time domain digital signal  
5 and the processed time domain digital signal to a  
second computer.

4. A data collection system according to  
Claim 2 further comprising means for transmitting at  
least one of said machine identifications, said  
10 measurement parameters, said time domain digital  
signal, said frequency domain digital signal and said  
predictive maintenance information to a second  
computer.

5. A data collection system according to  
15 Claim 1 further comprising means for displaying at  
least one of said machine identifications, said  
measurement parameters, said time domain digital signal  
and the processed time domain signal.

6. A data collection system according to  
20 Claim 2 further comprising means for displaying at  
least one of said machine identifications, said  
measurement parameters, said time domain digital  
signal, said frequency domain digital signal and said  
predictive maintenance information.

25 7. A data collection system according to  
Claim 1 further comprising power supplying means, for  
supplying power to said accelerometer.

8. A data collection system according to  
Claim 7 wherein said power supplying means electrically  
30 and mechanically couples said accelerometer output to  
said data acquisition card analog input.

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9. A data collection system according to  
Claim 8 wherein said power supplying means is  
responsive to said data acquisition card, for supplying  
power to said accelerometer when said data acquisition  
5 card is activated.

10. A data collection system according to  
Claim 1 wherein said signal processing means comprises  
software modules which execute on said portable  
computer.

10 11. A data collection system according to  
Claim 1 wherein said data acquisition card is a PCMCIA  
data acquisition card.

12. A data collection system according to  
Claim 1 wherein said data acquisition card is a sound  
15 card.

13. A power supply for an accelerometer  
comprising:

a power supply housing;  
an accelerometer battery power supply in said  
20 power supply housing, which provides sufficient power  
for an accelerometer;

output means, for electrically and  
mechanically connecting said accelerometer battery  
power supply to an accelerometer, and for receiving  
25 accelerometer signals from said accelerometer;

input means, for electrically and  
mechanically coupling said accelerometer battery power  
supply to an external device, for receiving a control  
signal from the external device and for providing said  
30 accelerometer signals to the external device;

said accelerometer battery power supply being  
responsive to said control signal to activate said

accelerometer battery power supply to supply power for an accelerometer to said output means.

14. A power supply according to Claim 13 wherein said accelerometer power supply is responsive 5 to absence of said control signal to deactivate said accelerometer battery power supply.

15. A power supply according to Claim 14 wherein said input means provides said accelerometer signals to the external device notwithstanding absence 10 of said control signal.

16. A power supply according to Claim 13 further comprising battery charging means for charging said accelerometer battery power supply.

17. A power supply according to Claim 13 15 wherein said input means comprises means for electrically and mechanically coupling said accelerometer battery power supply to a PCMCIA sound card.

18. A power supply according to Claim 13 20 wherein said output means comprises an MS3106 accelerometer connector.

19. A data collection system for measuring and collecting vibration data from machines, said data collection system comprising:

25 a portable computer including:  
a portable computer housing;  
a portable computer battery power supply within said portable computer housing to supply power to said portable computer; and  
30

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an expansion slot in said portable computer housing;

5 a data acquisition card mechanically and electrically coupled to said expansion slot; and

10 an accelerometer power supply including:

15 a power supply housing;

an accelerometer battery power supply within said power supply housing which provides sufficient power for an accelerometer;

means for electrically and mechanically coupling said accelerometer power supply to said data acquisition card;

and

means for electrically and mechanically coupling an accelerometer to said accelerometer power supply.

20 20. A data collection system according to Claim 19 wherein said portable computer further includes:

25 a database including a plurality of machine identifications and associated measurement parameters;

user input means for user selection of a machine identification for measurement; and

30 signal processing means, for processing accelerometer signals according to the measurement parameters associated with the selected machine identification.

21. A data collection system according to Claim 20 wherein said portable computer further includes:

signal analyzing means, responsive to said signal processing means, for analyzing the processed signal to produce predictive maintenance information.

22. A data collection system according to  
5 Claim 19 wherein said portable computer further includes:

means for transmitting data to a second computer.

23. A data collection system according to  
10 Claim 19 wherein said accelerometer power supply is responsive to said data acquisition card, for supplying power to an accelerometer when said data acquisition card is activated.

24. A data collection system according to  
15 Claim 19 wherein said signal processing means and said signal analyzing means comprise software modules which execute on said portable computer.

25. A data collection method for measuring and collecting vibration data from machines, said data collection method comprising the following steps which are all performed in a portable battery powered computer:

allowing user selection of a machine identification for measurement;

25 processing said time domain accelerometer signal according to measurement parameters associated with the selected machine identification to produce a digital signal; and

30 analyzing said digital signal to produce predictive maintenance information.

26. A data collection method according to  
Claim 25 wherein said processing step is preceded by  
the step of:

5 sampling and digitizing an analog  
accelerometer signal to produce the time domain  
accelerometer signal.

27. A data collection method according to  
Claim 25 further comprising the step of transmitting at  
least one of said machine identifications, said  
10 measurement parameters, said time domain accelerometer  
signal, said frequency domain digital signal and said  
predictive maintenance information to a second  
computer.

28. A data collection method according to  
15 Claim 25 further comprising the step of displaying at  
least one of said machine identifications, said  
measurement parameters, said time domain accelerometer  
signal, said frequency domain digital signal and said  
predictive maintenance information.

20 29. A data collection method according to  
Claim 25 wherein said digital signal is a frequency  
domain digital signal.

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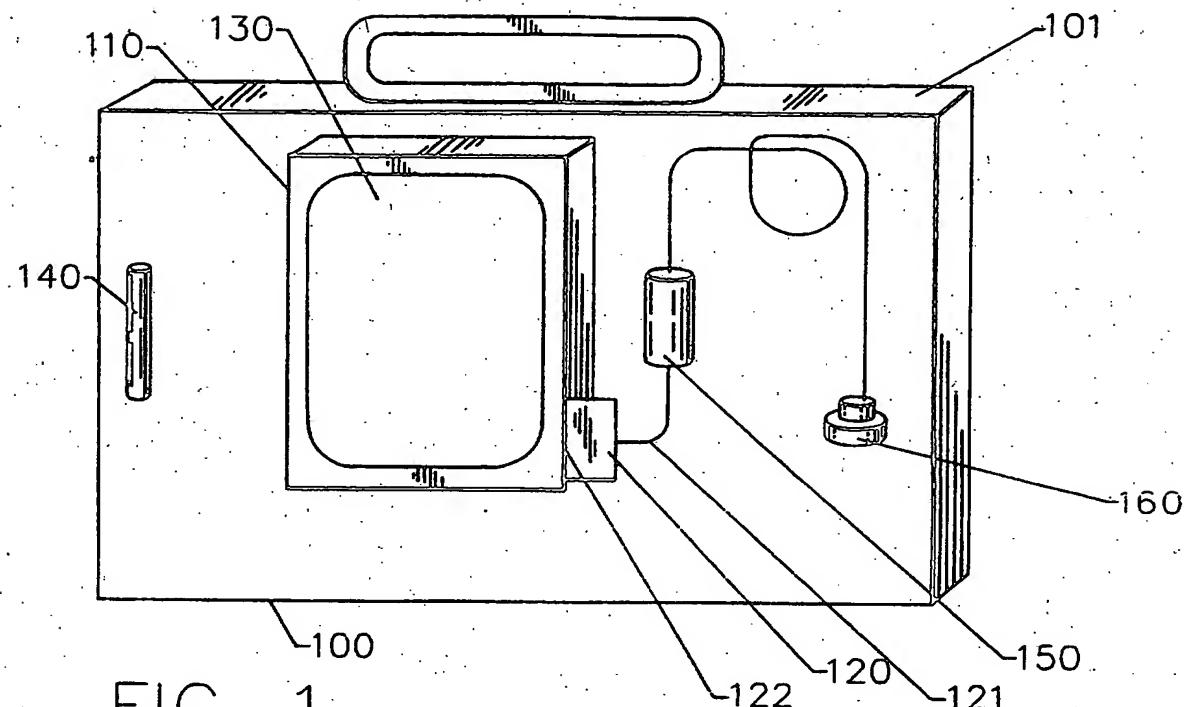


FIG. 1.

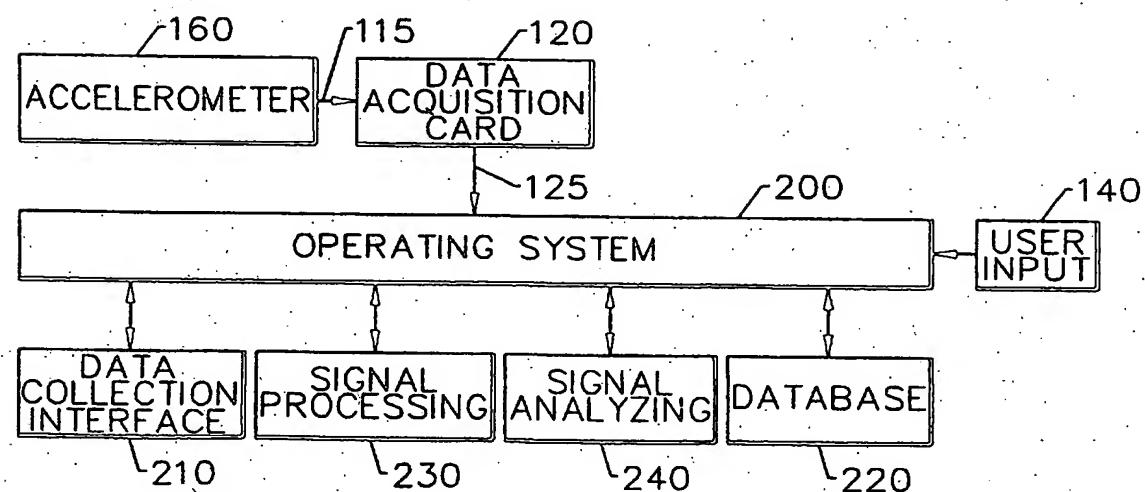


FIG. 2.

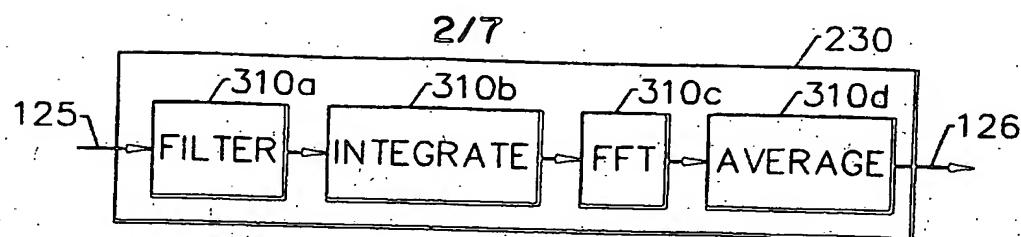


FIG. 3.

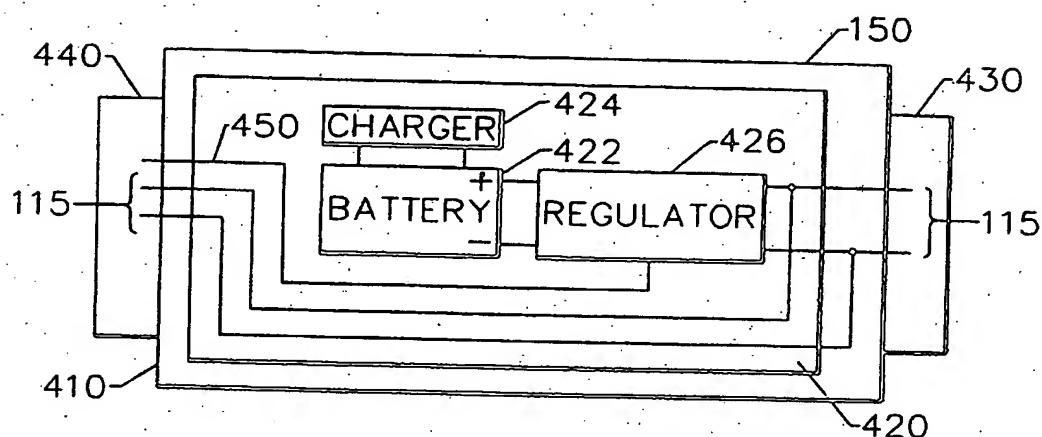


FIG. 4.

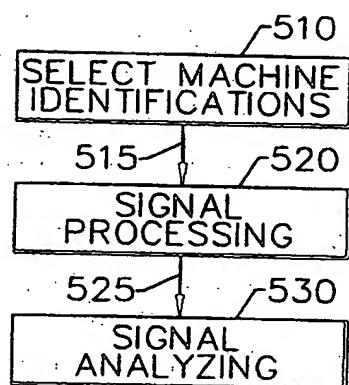


FIG. 5a.

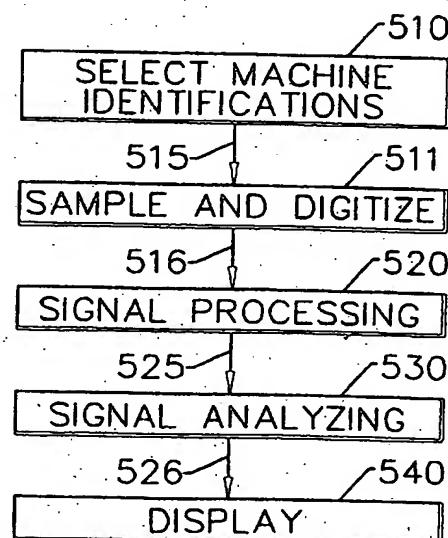


FIG. 5b.

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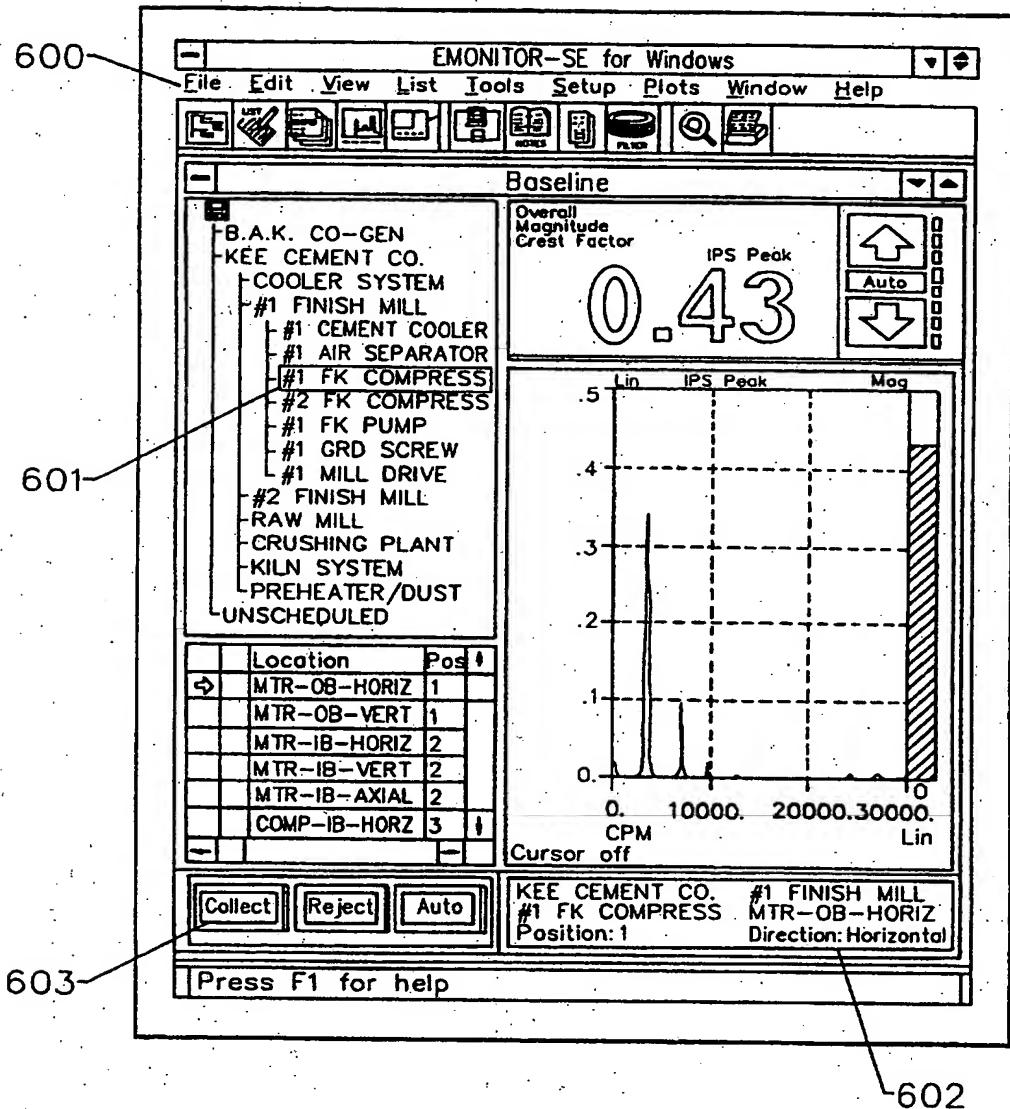


FIG. 6a.

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FIG. 6b.

610

EMONITOR-SE for Windows-[Data History]

File Edit View List Tools Setup Plots Window Help

LAST FILTER NOTES

LOCATION ID POS DIRECTION CATEGORY RPM DES

MTR-OB-HORIZ 1 Horizontal Standard Machine 1,765.0

MTR-OB-VERT 1 Vertical Standard Machine 1,765.0

MTR-IB-HORIZ 2 Horizontal Standard Machine 1,765.0

MTR-IB-VERT 2 Vertical Standard Machine 1,765.0

MTR-IB-AXIAL 2 Axial Standard Machine 1,765.0

COMP-IB-HORIZ 3 Horizontal Standard Machine 1,765.0

COMP-OB-HORIZ 4 Horizontal Standard Machine 1,765.0

DATA TYPE UNITS COLLECTION FILTER S

Magnitude ips STD(KCPM) 60 None Alw

Spectrum ips STD(KCPM) 60 None Alw

Magnitude q's STD G's Hi Freq High Frequency Alw

612

B.A.K. CO-GEN  
KEE CEMENT CO.  
COOLER SYSTEM  
#1 FINISH MILL  
#1 CEMENT COOLER  
#1 AIR SEPARATOR  
#1 FK COMPRESS  
#2 FK COMPRESS  
#1 FK PUMP  
#1 GRO SCREW  
#1 MILL DRIVE  
#2 FINISH MILL  
RAW MILL  
CRUSHING PLANT  
KILN SYSTEM  
PREHEATER/DUST  
MAIN BAGHSE FAN  
KILN ID FAN  
E. DUST COMPRESS

IN. DUST COMPRESS  
N. DUST PUMP  
S. DUST PUMP  
REV AIR FAN #1 N  
REV AIR FAN #2 S  
UNSCHEDULED

Date Time Storage Flags Amplitude Max Machine

06/04/1994 11:18:00am Archive 774265 1765

05/04/1994 11:10:00am Archive 6262109 1765

04/04/1994 10:54:00am Archive 5023031 1765

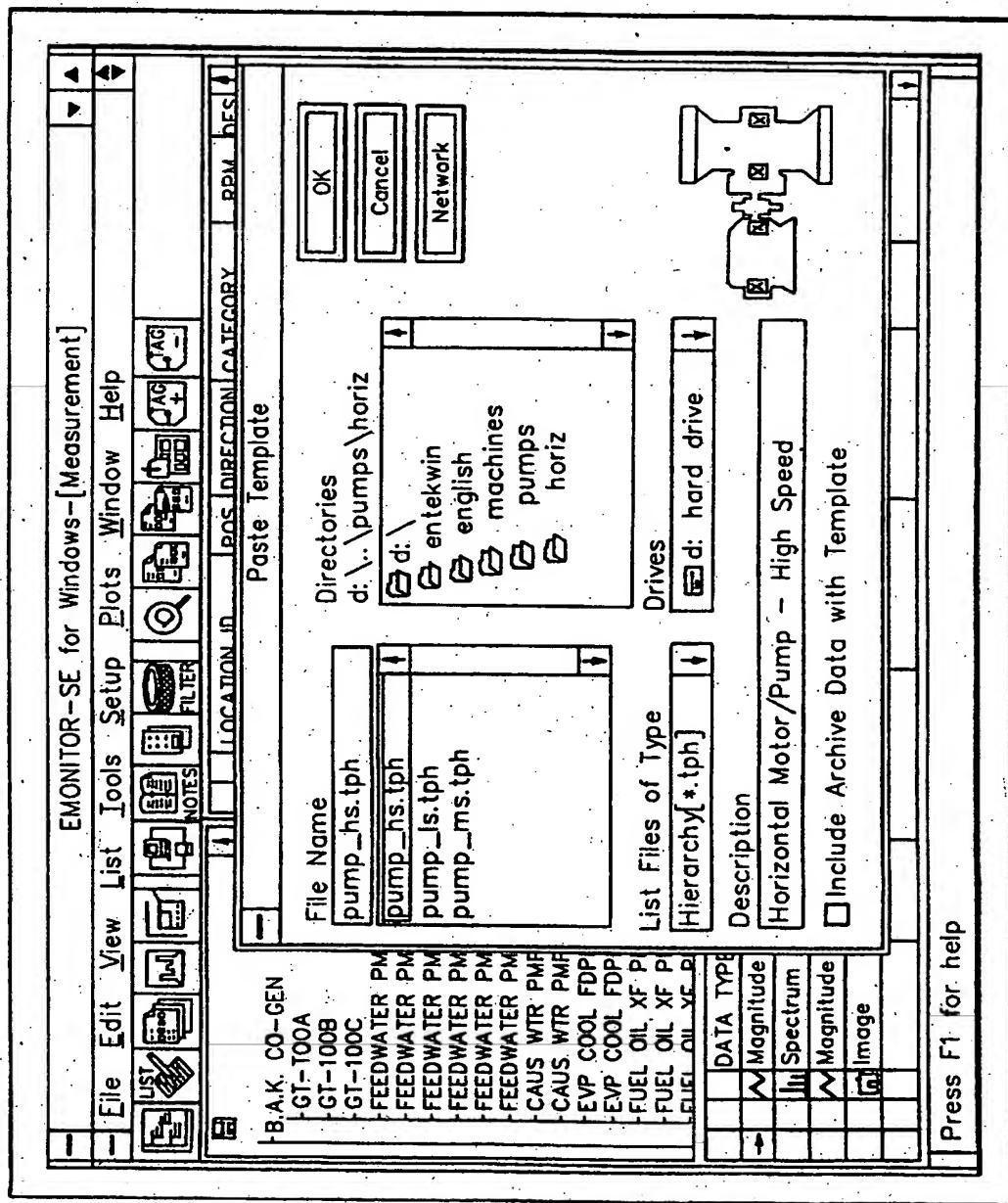
03/04/1994 10:46:00am Archive 5877681 1765

611

Press F1 for help.

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FIG. 6c.



SUBSTITUTE SHEET (RULE 26)

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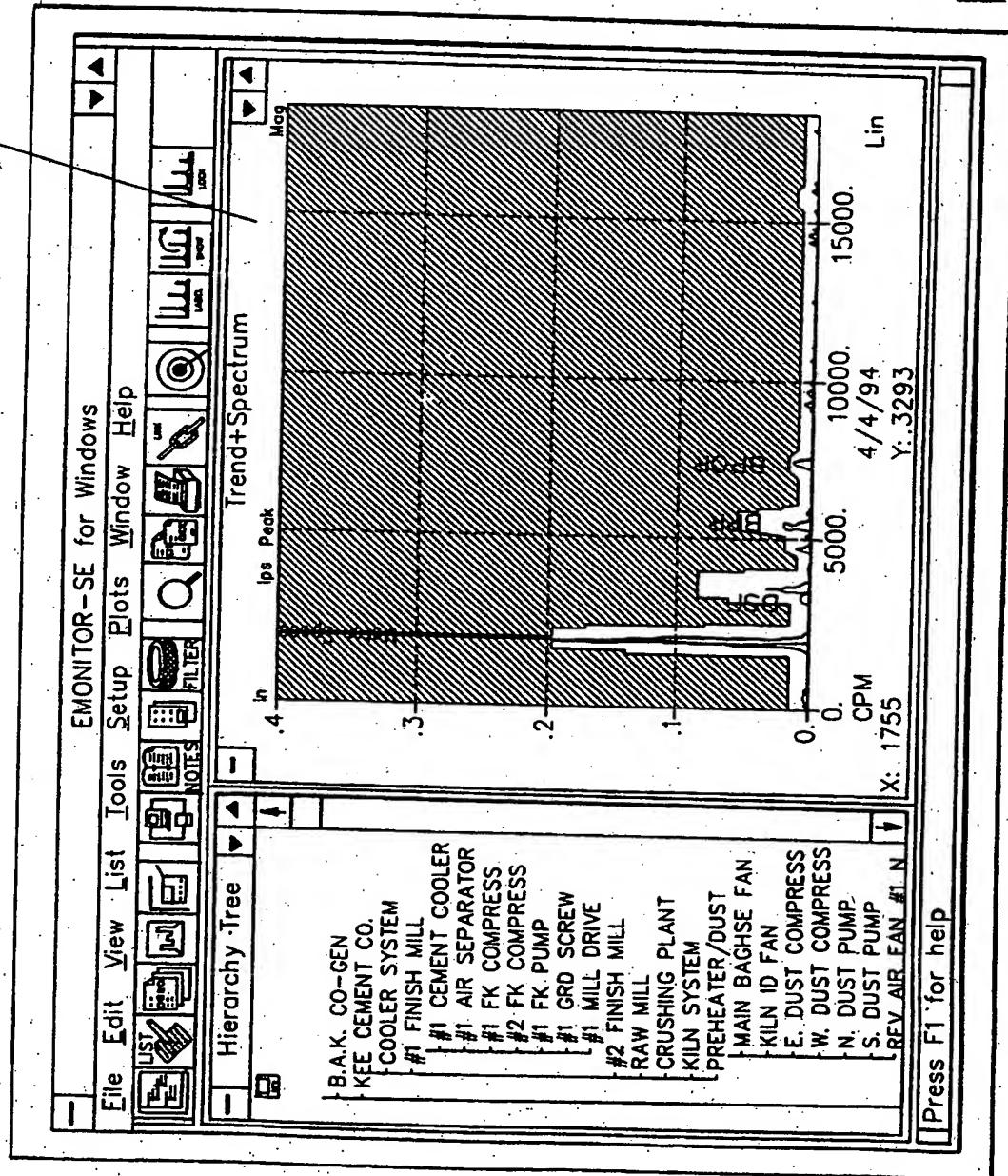


FIG. 7.

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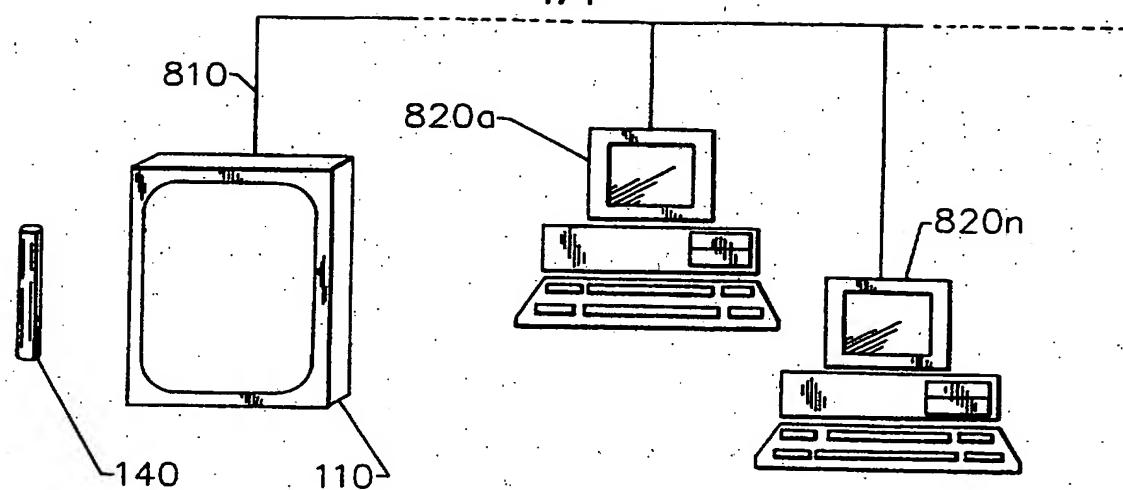


FIG. 8.

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 96/15383

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 6 G01H1/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 885 707 A (NICHOL ROBERT E ET AL) 5 December 1989 see column 1, line 58 - column 2, line 64; figures 1,2 see column 3, line 50 - line 61 see column 9, line 57 - line 61 see column 1, line 17 - line 29 ---	1-4,10, 19-29
A	US 4 520 674 A (CANADA RONALD G ET AL) 4 June 1985 see column 2, line 62 - column 5, line 13 see column 11, line 32 - line 60 see column 6, line 42 - column 7, line 6 ---	16
X	US 4 520 674 A (CANADA RONALD G ET AL) 4 June 1985 see column 2, line 62 - column 5, line 13 see column 11, line 32 - line 60 see column 6, line 42 - column 7, line 6 ---	1-10,13, 14

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
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- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&\* document member of the same patent family

1

Date of the actual completion of the international search

12 February 1997

Date of mailing of the international search report

19.02.97

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Fax (+31-70) 340-3016

Authorized officer

Anderson, A

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 96/15383

## C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	PATENT ABSTRACTS OF JAPAN vol. 95, no. 010 & JP 07 253352 A (TLV CO LTD), 3 October 1995, see abstract -----	7,8,13, 19

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.  
PCT/US 96/15383

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-4885707	05-12-89	NONE	
US-A-4520674	04-06-85	NONE	